



**CENTER FOR THE COMMERCIAL DEPLOYMENT  
OF TRANSPORTATION TECHNOLOGIES (CCDoTT)**  
**California State University, Long Beach**

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Date: February 22, 2006

From: Center for the Commercial Deployment of Transportation Technologies

To: Business Transportation and Housing Agency  
California Environmental Protection Agency

**Subject: Recommended changes to Page VI-4 of the Goods Movement Action Plan, Phase II Progress Report: Draft Framework for Action (Draft (12/20/05))**

Attachments:

- (1) *Urban Maglev Freight Container Movement at the Ports of Los Angeles/Long Beach Paper by Dr. Ken James and Dr. Sam Gurol*
- (2) Recommended changes to Page VI-4 of the Goods Movement Action Plan, Phase II Progress Report: Draft Framework for Action (Draft (12/20/05))

1. In review of the Goods Movement Action Plan, Phase II Progress Report: Draft Framework for Action (Draft (12/20/05), we found Table VI-3: System Technology Enhancements, to be a very inaccurate representation of the capabilities of a Freight system based on Maglev technology.
2. Attachment (1) provides background information on two potential systems that could be applied to cargo movement within and from the Ports of LA and LB to a remote port site. The systems use currently available Maglev systems that are either in operation or have working prototypes.
3. It is assumed that the evaluation provided in Table VI-3 is based on the assessment of passenger maglev system done by the FRA in its Report to Congress. A dedicated freight maglev system is a very different system and must be assessed in a dedicated commercial freight environment and not as a passenger system being used for freight.
4. In Attachment (2) we have applied the criteria established in the Goods Movement Action Plan to the capabilities of the system discussed in Attachment (1) and provided short explanations for the changes to the original table.
5. It is request that the tables be reviewed with the capabilities discussed in Attachment (1) considered.
6. If you have any questions, please contact Steve Hinds at CCDoTT, 562.985.2259 or [shinds@csulb.edu](mailto:shinds@csulb.edu)

Thank you for your consideration,

A handwritten signature in black ink, appearing to read "Steve Hinds", is written over a horizontal line.

Steve Hinds  
Program Administrator

## **Urban Maglev Freight Container Movement at the Ports of Los Angeles/Long Beach<sup>1</sup>**

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**Abstract:** Existing sea-based ports are typically surrounded by major metropolitan areas, which require movement of shipping containers through those areas and places unwelcome strains on the existing infrastructure. A case in point is the Port of Los Angeles/Long Beach (LA/LB), the nation's largest and most important port. Almost one-half of the nation's port-related traffic passes through the Los Angeles metropolitan area on its way into the interior. The Alameda rail corridor—developed to help accommodate the unprecedented growth of container traffic coming to and from the Port—has not significantly reduced the impact of freight movement on the Los Angeles community. A number of terminals at the Port must truck containers to the terminus of the Alameda corridor, four (4) miles from the Port, causing significant congestion and diesel pollution in the surrounding community. Costly proposals to expand the area's existing highway system in conjunction with a growing recognition of the dangers of Diesel Particulate Emission (DPE) have prompted a novel approach to the container movement challenge. This approach utilizes a proven Maglev "conveyor belt" technology that shows promise for both short-haul urban freight movement and interstate-bound containers. The application of this technology to container freight movement at the Port and beyond will reduce both highway congestion and pollution throughout the Los Angeles area.

<sup>1</sup>Work sponsored by the Center for the Commercial Deployment of Transportation Technology (CCDoTT) through funding from the Office of Naval Research (ONR)

**1-Introduction:** Over the past several years the Center for the Deployment of Transportation Technologies (CCDoTT) has developed the *agile port concept* (CCDoTT, 2003) that involves moving containers from the port, where storage space is scarce, to inland ports or Intermodal Container Transfer Facilities (ICTFs) where containers can be redirected to local trans-shippers, or organized into transcontinental trains. The weakest link in this scenario is the dedicated link between the port and remote facility. Thus, for the last three years, CCDoTT has prioritized the definition of a new paradigm in moving containers out of the Ports of LA/LB. The approach CCDoTT pursued uses freight optimized Maglev technology for a variety of supply chain applications. This is very different from the concept of passenger Maglev, in that freight Maglev has a known ridership—container volume—and the containers are all going to the same places—ICTFs.

This container movement paradigm has several requirements. The first is to accommodate projected port growth so the economic base of the Southern California region, and the entire county, can continue to grow. The second is to relieve pressure on the existing highway infrastructure which cannot well handle its current load. The third is

to improve the quality of life, not just at the port, but throughout the region. An adage attributed to Einstein, appropriate to the CCDoTT paradigm shift is: "You cannot solve problems with the same technologies that caused them." These three (3) requirements define the parameters of a new container transport approach.

Growth of the Ports of LA/LB is essential because it provides jobs and produces wealth within the region. A recent study shows that newly created logistics jobs have in fact more than made up for manufacturing jobs lost due to industry moving from Southern California, and they are higher paying than manufacturing jobs requiring similar skills (Husing, 2005). Acreage at the port rents for upwards of \$250,000/acre/year producing income for cities and state (CCDoTT (2), 2005). Supplies for military sustainment have historically passed through the port, and military planners need to continue to be able to count on the port as a means of shipping supplies to military depots overseas. And, most strategically, almost one half of all the imports to this country come through the Ports of LA/LB (Aschemeyer, 2005). An increase in the size of the Ports is not possible; there clearly is not room to expand. To meet the projected container influx, port throughput must be increased. A container movement approach should have the capability of moving an additional five (5) million or more forty foot containers per year from the port.

Traffic problems on Southern California freeways are legendary. The estimate of 11 \$Billion/year in productivity losses in Los Angeles and Orange counties, due to freeway congestion is not surprising (Schrank, 2005). Adding more containers from the Ports of LA/LB year after year will likely bring the region to a standstill. Even if local governments, political action groups, and community leaders could agree on how and where rail or highway could be expanded, these means of container transport still have a wide footprint (surface area utilized) and cannot easily be elevated. To reduce the stress on the existing Southern California infrastructure a container movement approach should be capable of high throughput but have a smaller footprint than road or rail.

Stationary sources of pollution such as electrical power plants have made great strides in reducing air pollution with massive "scrubbers", and automobiles have continued improving over the years; air quality for the Southern California region has markedly improved as a result. One pollutant, however, remains problematic: Diesel Particulate Emissions or DPE. This pollutant is different from gaseous pollutants in that it is localized to areas where diesel engines operate such as the port, truck/train intermodals, and along freeway and rail corridors. The effects of DPE are devastating. More than thirty (30) human epidemiological studies have found that diesel exhaust increases cancer risks, and a 1999 California study found that diesel exhaust is responsible for seventy (70) percent of cancer risks from air pollution (Bailey, 2005). Only recently has the danger of having homes and schools close to sources of DPE been recognized. Figure 1 shows an Air Quality Management District (AQMD) (MATES II, 2000) study of how DPE is concentrated around the port and transport paths. To alleviate the severity of the DPE problem for the entire community, a container movement approach should exploit fixed power sources that produce minimal pollution

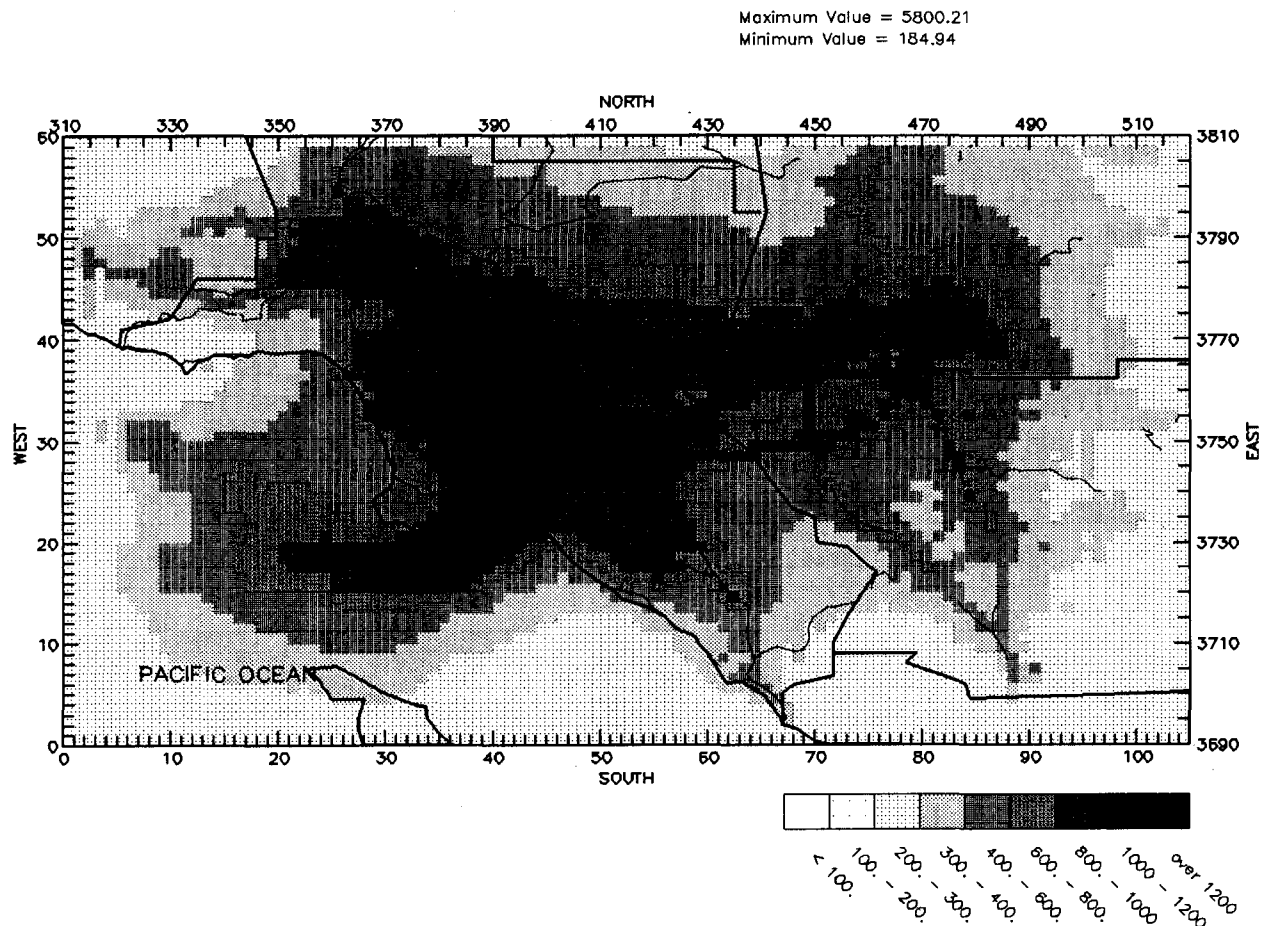


Figure 1. Model Estimated Cancer Risk/Million Population For The Los Angeles Basin

The aforementioned economic, congestion and pollution issues facing urban freight movement from the Ports produce conflicting constraints to balancing Southern California's economic future with the region's quality of life. The international trade industry (ships, trucks and trains) has been identified as a major source of pollution due to the heavy use of diesel power. Port expansion plans have run into a community environmental "road block;" more rigorous Environmental Impact Reports (EIRs) are being demanded. Responding to community pressures, some elected officials are discussing limits on port emissions; these would also serve to limit port growth. California state legislators have fired off a barrage of bills aimed at regulating and changing the way goods are handled, workers are compensated, and pollution is curbed at California ports and transportation hubs. Several of these bills add constraints to operations while others add costs to the movement of containers both within and beyond the Ports' region. From an economic perspective, these bills impact the economies of the Ports and cargo movement and therefore affect the cost of doing business. Maglev presents a "win-win" solution; moving containers in sufficient number and speed to allow continued economic growth, while alleviating congestion and pollution throughout the Southern California basin.

**2-New Paradigm for Container Movement:** Maglev technology is a solution that can help solve the problems created by the technology responsible for the congestion and pollution Southern California is faced with today. It provides the needed balance between more and better jobs of an expanding economy and a quiet, clean, and safe environment for the people who have those jobs. Again, "one cannot solve problems with the same technologies that caused them."

Maglev is not a new concept. Recently, the world's first commercial urban Maglev and high-speed Maglev passenger lines have gone into service in Japan and China, respectively. Application of Maglev technology to a freight-only system is an innovative alternative to conventional road or rail infrastructure. The environmental and community constraints on expanding conventional means of container transport through the Los Angeles basin indicate that a Maglev freight system will have similar capital costs and lower operational costs than highway and rail, thus providing a cost-competitive solution for urban areas (TransRapid, 2004). The referenced study involved an Electromagnetic System (EMS) design by TransRapid, the German developer of the world's first commercial Maglev system. Recent work at Lawrence Livermore Laboratory and General Atomics (GA) has shown that an Electrodynamic System (EDS) Maglev also has significant potential benefits for transporting containers.

**3-Maglev Urban Freight Technologies:** Maglev technology is a way of floating container carriages utilizing a magnetic field to move them along a guideway without any moving parts. It is not a new technology; Maglev was conceived decades ago. Only in the last fifty (50) years has it been applied to real world situations. There are two (2) forms of Maglev. ElectroMagnetic Suspension (EMS) uses electronic feedback control to lift the carriage with *attractive* magnetic force. This system was developed by the German firms Siemens and Krupp in a joint venture named TransRapid. The TransRapid carriage is pulled forward by a Linear Synchronous Motor (LSM) that is similar to a typical electric motor, but unwound and laid lengthwise along the guideway.

The second Maglev form is ElectroDynamic Suspension (EDS) which was conceived in the United States during the 1960s, and later developed by Japan. EDS employs a magnet moving above a conductive plane producing an opposite image of the magnet and generating magnetic *repulsion* that causes the carriage to lift away from the guideway. Fifty years ago the only magnets powerful enough to be used for this form of Maglev were superconducting magnets, which at that time were laboratory oddities. It was not until the late 1980's with the development of rare-earth magnets such as Neodymium Iron Boron (NbFeB) that EDS technology became realizable without cryogenics. EDS still had to wait until the 1990s for the development at Lawrence Livermore Laboratories of Halbach array technology (Heller, 2005). Today General Atomics has licensed the technology, and built a full-scale 400-ft. EDS Maglev test track at their headquarters in San Diego. This system also uses a linear synchronous motor for propulsion. The advantage of the EDS magnetic suspension system is its passive nature: there are no on-board power supplies to generate the lift forces (all that is needed is forward motion, generated by the LSM windings in the track). In addition, an EDS suspension leads to significantly greater air gaps resulting in more lenient guideway construction tolerances, with resultant cost savings potential.

Maglev technology can accommodate port container growth with on-dock service, reduce stress on the existing infrastructure (since it has a small footprint and can be elevated), and, by using fixed power sources, produce negligible air and noise pollution. In addition, economic projections of Maglev usage are considerably more straightforward for

freight compared with moving passengers. The amount of freight moved per day is known, and the system can be designed to accommodate current and future needs. By contrast, a passenger system relies on a minimum (and sometimes difficult to project) ridership for economic viability. Two years ago, CCDoTT approached TransRapid with the concept of freight Maglev. TransRapid recognized the economic advantages of CCDoTT's "conveyor" approach and began working with CCDoTT on a first-order model from a port to inland intermodal system. Figure 2 shows the TransRapid freight-optimized design with attracting magnets lifting the carriage.

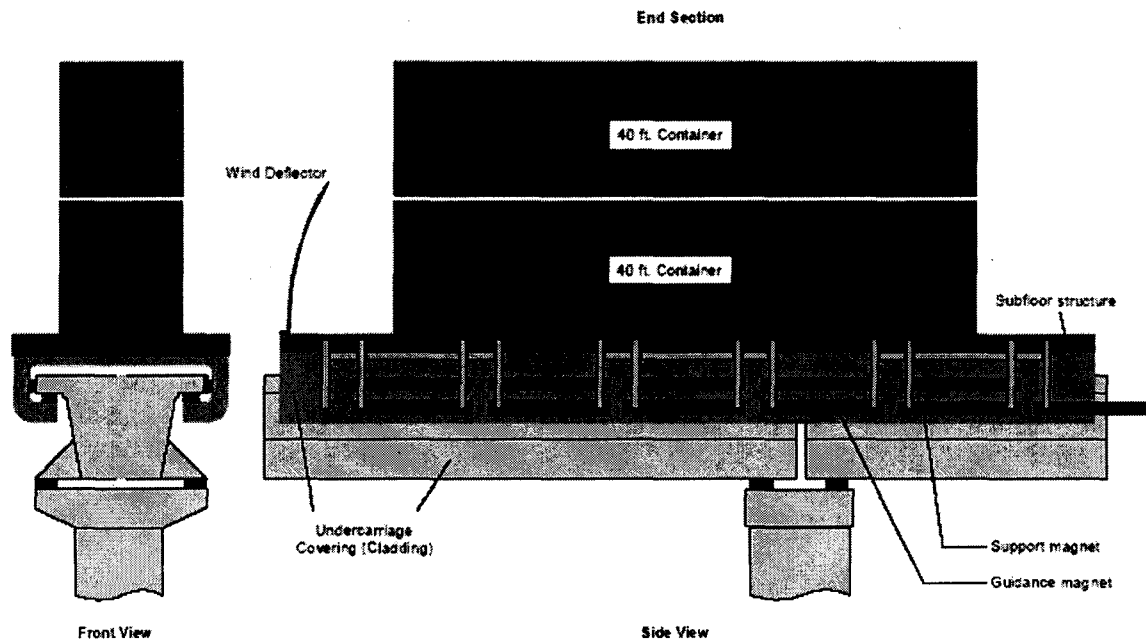


Figure 2 TransRapid Freight Optimized Maglev Carriage

TransRapid engineers also performed a propulsion power, system architecture analysis, as shown in Figure 3 (TransRapid, 2004).

CCDoTT Southern California Freight Initiative: Transrapid Maglev System  
 Inland Empire Route: Track Scheme / Propulsion Layout (schematic layout, not to scale)

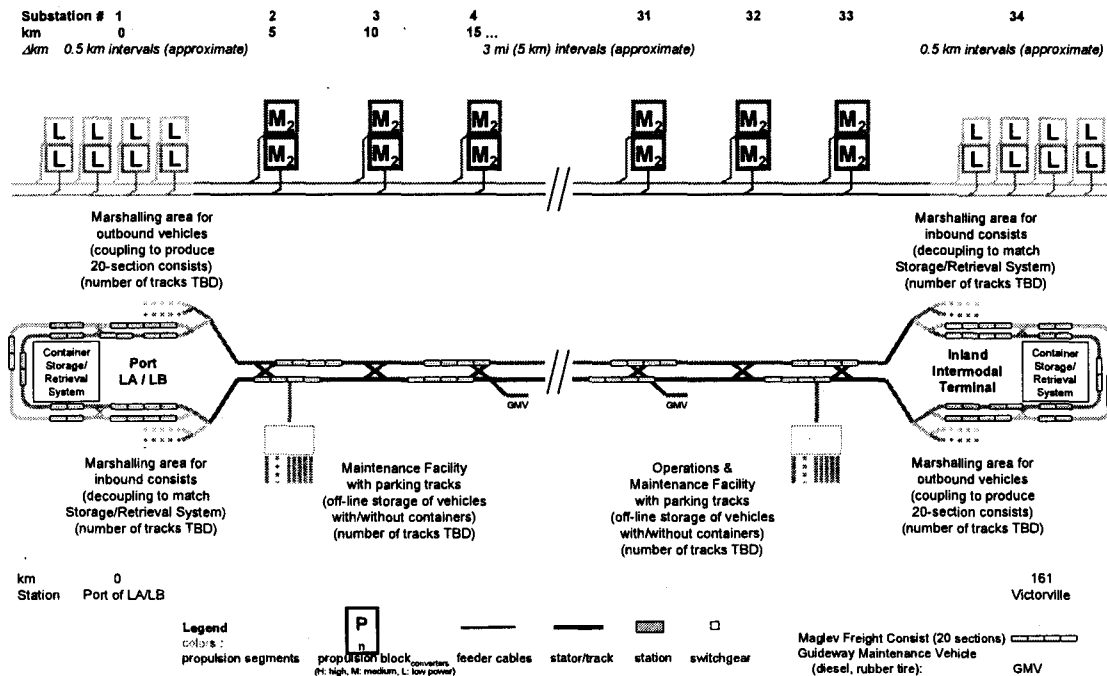


Figure 3 TransRapid's Port to Inland Intermodal Layout

The ElectroDynamic Suspension approach, developed by General Atomics, is passive in that once the carriage, which initially rests on wheels, is propelled by the linear synchronous motor to a velocity of around 5 to 10 miles/hour, when lift is achieved. Figure 4 shows a schematic of the passive magnet, Halbach array configuration relative to the transposed conductor guideway. General Atomics has built a full-scale prototype of a passenger EDS Maglev system at its facility in San Diego consisting of a carriage, guideway and power distribution system. Experimental results from system tests show the magnitude of the required velocity for "lift-off" as well as the measured drag as a function of velocity.

Like TransRapid, General Atomics proposes enhancing their passenger Maglev carriage to carry shipping containers. Figure 5 is a detailed sketch of the existing passenger carriage used for system evaluation.

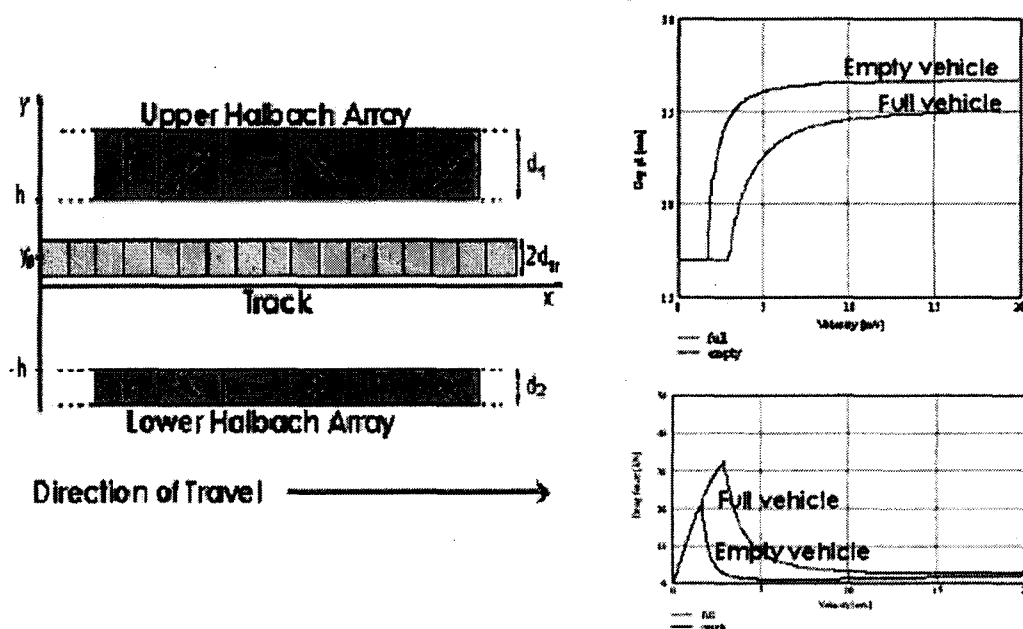


Figure 4 General Atomic's EDS schematic with Results for Full-Scale Freight Prototype

An area where significant Maglev system cost optimization can be realized involves the guideway and associated components. The EMS system with its electronic feedback control, operating with a nominal air gap on the order of 10 millimeters, has inherently tight tolerances, on the order of millimeters—between the lifting magnets and the guideway. Camphor and support spacing of an elevated guideway for an EMS system are critical design factors. An EDS system lifts away from the guideway—on the order of 20 to 30 millimeters—allowing more versatility in guideway design, with more lenient tolerances in component fabrication and assembly. General Atomics has considered various forms of prefabricated guideway sections as shown in Figure 6.

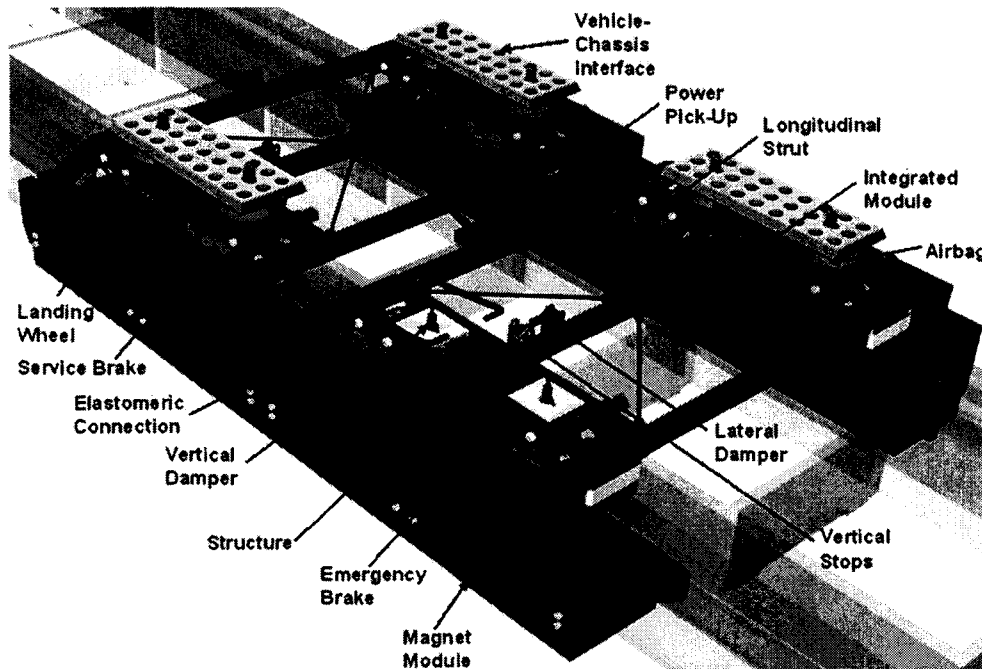


Figure 5 Detailed View of GA's EDS Maglev Carriage

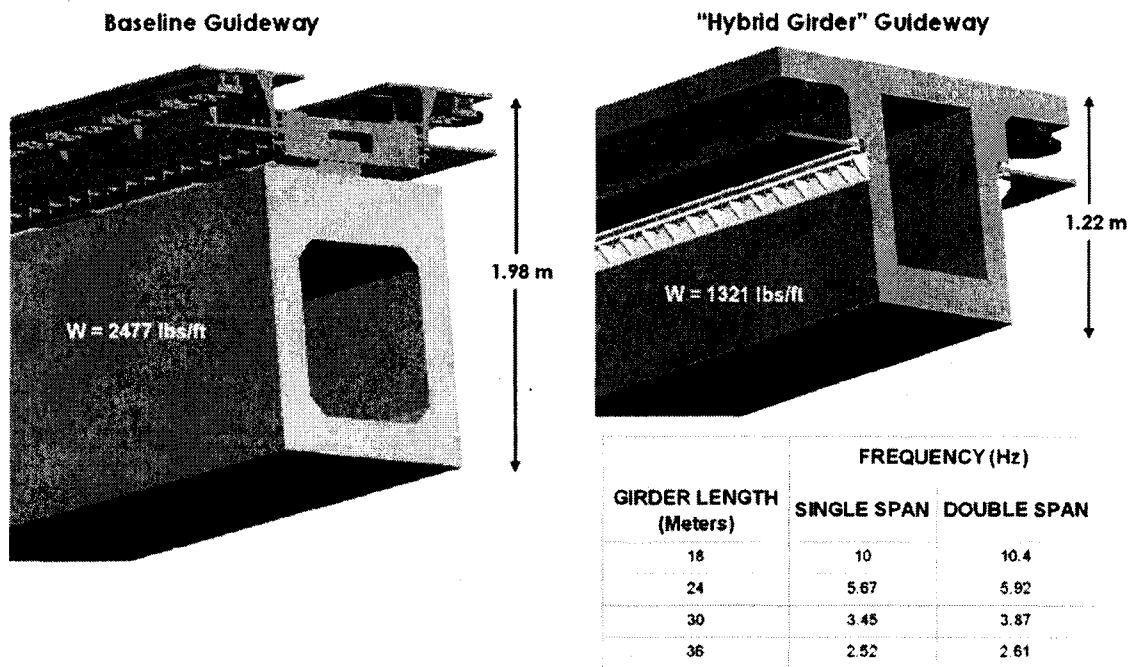


Figure 6 Two forms of EDS Maglev Guideway Considered by General Atomics

**4-CCDoTT's FY'04 Freight Maglev Program:** As described previously, CCDoTT initialized its investigation into freight optimized Maglev with TransRapid, the only

commercially available Maglev manufacturer in the world at that time. That company provided CCDoTT with a preliminary freight system design and approximate operational and capital costs, based on their experience in Shanghai. CCDoTT also worked with Automation Associates to develop a 1<sup>st</sup> order model of the Southern California rail and road infrastructure to determine the impact of a Maglev system on the transportation arteries in the region. Manalytics Inc. provided cost data for moving containers through Southern California by road and rail as well as existing and projected container traffic.

CCDoTT's findings for FY'04 were most encouraging. The increased speed and density of a dedicated express container transporter connecting the port to the Inland Empire as well as Victorville, a railhead for the Burlington Northern Santa Fe (BNSF), and Beaumont, a railhead for the Union Pacific (UP), showed Maglev technology could accommodate port growth and carry an additional five (5) million containers per year (TransRapid, 2004). Why the elevated Maglev with its narrow footprint can carry more containers than a much wider freeway, involves the consistent 70 mph speed of the containers on the conveyor system. The benefits of the port-to-inland corridor approach are numerous. Container traffic bound for the continental U.S. is separated from commuter traffic and trucks servicing distributors and manufacturers within this region, making freeways more useful. Reduced congestion lessens the need to expand freeways. Less congestion also allows more reliable military movement to the ports. As a side benefit, there are plans for a military staging area at the Southern California Logistics Center, the former George Air Force Base, which would benefit from the use of commercial Maglev. The land in these inland areas is cheaper for warehouse transshippers: \$250,000/acre/year at the Ports vs. \$250/acre/year in Hesperia (CCDoTT (2), 2005). Since Maglev is computer controlled and carriages are operated without on-board personnel, security is also improved. Most importantly, the projected Maglev system can move five (5) million or more containers with minimal air and noise pollution.

CCDoTT considered a number of rights-of-way as shown on the map in Figure 7. Perhaps the most promising route is the one that follows I-15 through the Cajon pass. Another attribute of Maglev freight optimized systems is their ability to climb steep grades. Both the EMS and EDS freight-optimized Maglev systems are projected to be able to carry containers up a 6% grade, while rail can only handle 3%. This is why trains must take a circuitous route through the pass and require expensive tunneling. The 6% maximum grade for freight Maglev matches the maximum grade allowed on the Interstate highway system, suggesting Maglev rights-of-way along interstate medians.

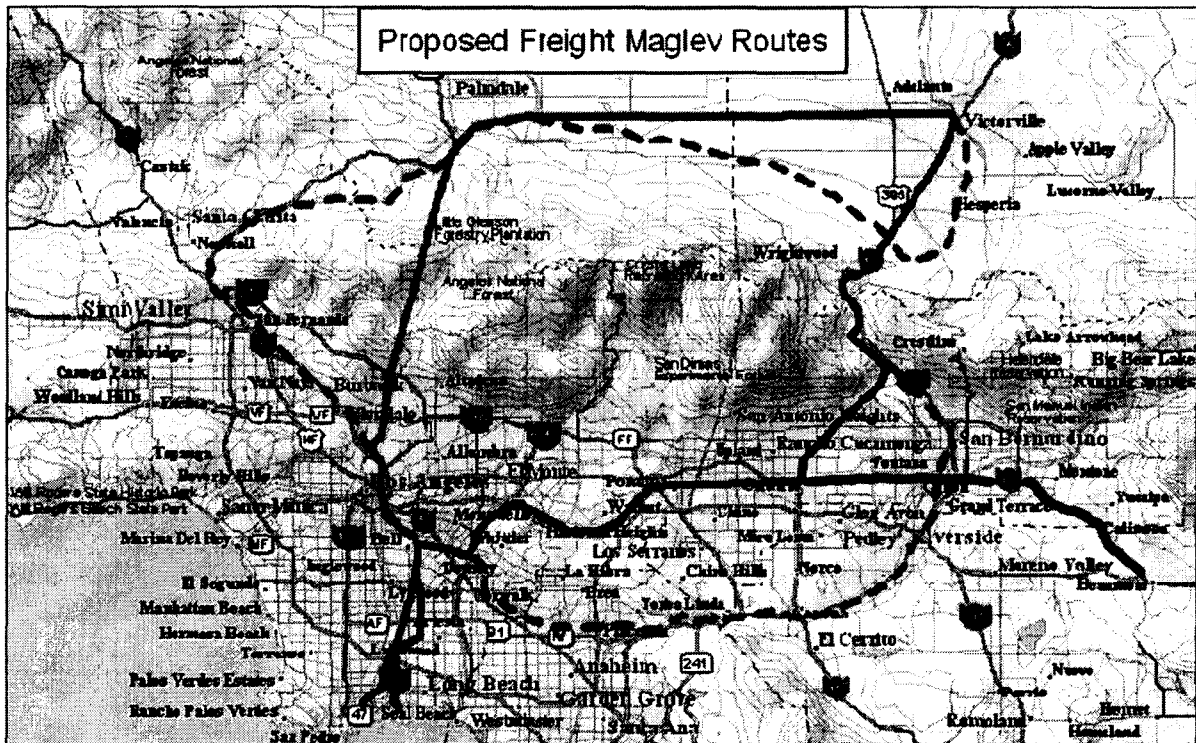
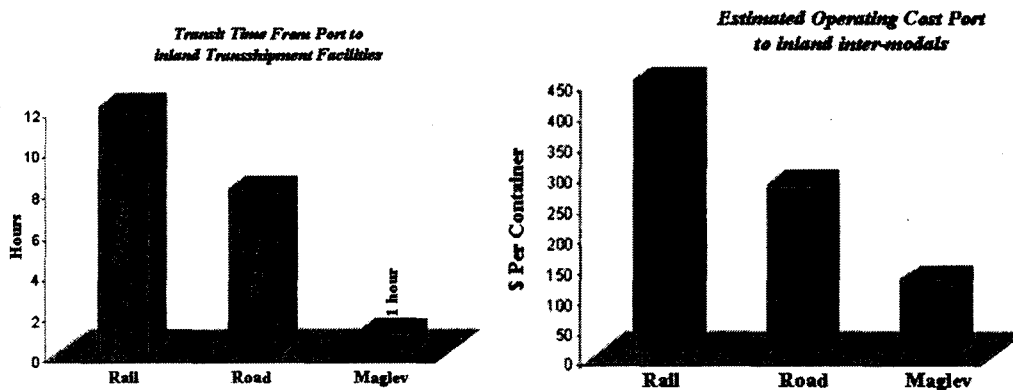


Figure 7 A Number of Proposed Rights-of-Way for the Port to Inland Intermodal Maglev

The charts in Figures 8,9 show the projected transit time and operational costs of sending a container from the port to an inland intermodal terminal. The one-way cost and time projections for the three container transport methods were determined by quotes from trucking firms (R & C Trucking, 2005), the trial Alameda Corridor "shuttle train" (CCDoTT(1)), and TransRapid power analysis. The energy required per trip for Maglev was estimated to be approximately five hundred (500) kWh per forty (40) foot container (TransRapid, 2004). Conventional lift-on/lift-off handling costs were added to this energy expense to arrive at the Maglev freight operational cost. Maglev costs fare very well when compared to shuttle trains presently under evaluation, to conventional truck portage, and includes the added benefit of negligible air and noise pollution.

An examination of capital costs must include the small footprint and the ease of elevation of the Maglev freight system, which makes its construction cost competitive with the costs of expanding highway and rail in the crowded Los Angeles basin. Highway costs are based on construction of a four lane elevated truck expressway with on and off ramps (MTA 2005) transitioning to widened freeways to allow for dedicated truck lanes. Rail costs are based on having to "trench" (drop below road level) several miles to eliminate grade crossings through east Los Angeles (Southern 2005). These are all very expensive propositions; Maglev technology can lead to very significant system cost savings.



Figures 8,9 Comparison of Rail, Highway, and Maglev Time to Delivery and Operational Cost per One-Way Trip from Port to Inland Intermodal, 100 miles Away

Maglev possesses operating cost margins that would encourage private investment. Figure 10 shows projected capital cost comparisons.

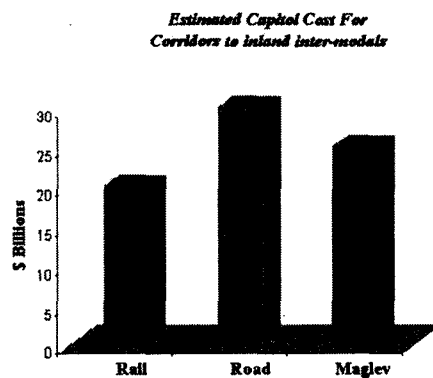


Figure 10 Comparison of Rail, Highway, and Maglev Capital Costs to Carry an Additional 5+ Million Containers per Year

For these capital expenditures, Maglev needs a freight system demonstration. Due to increased attention to the million+ truck trips per year moving containers from the gates of the terminals to the proposed new BNSF ICTF and existing truck traffic to the existing UP ICTF, the opportunity to put the first phase of the Maglev system into effect has materialized.

**5-CCDoTT's Ongoing FY'05 Freight Maglev Program:** The immediate application for Maglev Technology is the feeder system from terminals to ICTFs, which in reality eliminate short haul trucking from terminal to Alameda Corridor ICTFs and railheads. It provides a feeder system to get containers out of the Ports and will eventually be part of the larger and more comprehensive Maglev freight system.

What can happen with an automated Maglev conveyor increasing container throughput and port productivity? (1) Maglev would greatly enhance the economic viability of the Alameda Corridor. (2) Large reductions in harmful Diesel Particulate Emissions (DPE) would be attained. (3) Present trucking costs from terminals to ICTF of approximately \$125 (+\$90 lift costs) could be reduced by \$100 with freight Maglev, more if terminal container movement vehicles are outfitted with Maglev hardware to reduce lift-on/lift-off costs. Capital cost studies are presently the subject of a joint GA/CSULB proposal, as well as more detailed operating costs.

California State University is conducting a study on the engineering design and subsequent cost of the General Atomics (EDS) approach for container freight movement at the Ports. The EDS Maglev design will be projected onto the Port of Los Angeles / Long Beach / Alameda Corridor infrastructure to determine its feasibility as a means of transporting containers from the Port's terminals to the (ICTF) at the Alameda Corridor (Gurol, 2005). Comparisons of the Maglev system with a number of proposed, conventional solutions to Port throughput will be made. Resultant community impact will also be addressed.

CSULB working with GA, will address a number of tasks in this initial feasibility study. First, we will develop a list of operational and site-specific requirements for a cargo Maglev system. These requirements will be used to flow down requirements for the guideway, vehicles, levitation and propulsion magnets, propulsion power systems, and communication and signaling system. The existing GA Maglev test chassis, seen in Figure 11, will be used as the basis for modifying the magnetic systems to handle the loading requirements. The approach uses the dynamic data from the on-going GA chassis testing to scale to the required magnetic footprint area. Initial projections appear very promising that the magnetic system can easily handle the maximum loading. The guideway will also be re-configured to handle the maximum loading imposed by project cargo loads. We will evaluate the structure based on maximum allowable deflections in the girders (a large air gap can allow larger deflections, leading to potentially cheaper structures), and then design an overall system architecture based on the throughput requirements for cargo.

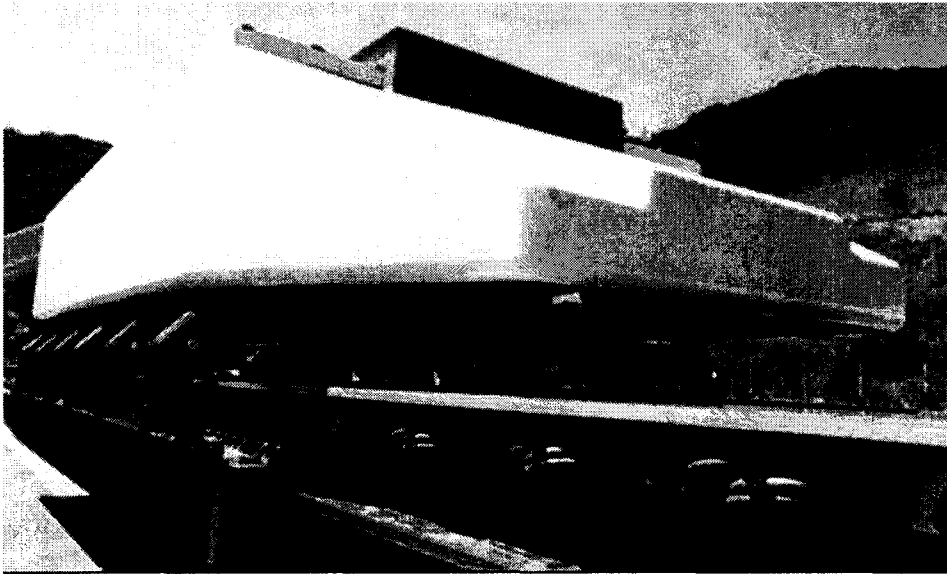


Figure 11 EDS Maglev Prototype at General Atomics, Diego, California.

Maglev technology has unique enabling features, which make it ideal for carrying cargo. First, the linear synchronous motor and friction-free magnetic suspension will result in a system which can accelerate much faster than conventional wheeled systems (0.15 g acceleration is typical); this leads to high throughput (short headways). In addition, the magnetic propulsion system can handle much greater grades (Maglev design is for 10%; 6% is needed for cargo). During the study, we will develop an architecture that takes full advantage of these features. The next steps will be to develop a cost estimate and schedule for the construction and operation of an initial 5-mile Maglev cargo demonstration system at the Port of Los Angeles.

**6-Conclusions:** Moving large numbers of containers quickly and efficiently from the Ports of LA/LB to transcontinental trains, trans-shippers, and Inland Empire warehouses is vital to the health of the Southern California economy. Equally important is the physical health of the region's citizens. A technology that moves containers with markedly reduced pollution as well as reduced traffic congestion is desperately needed (Press Telegram, 2005). This paper presents such a technology--Maglev, and describes how that technology can be projected onto the region's goods movement infrastructure; including possible routes, container throughput volume, capital expenditures, and operational costs.

**7-References:**

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CCDoTT(2) meeting with Long Beach Terminal Port Operator, December 10, 2005.

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**Recommended changes to Page VI-4, Table VI-3, of the *Goods Movement Action Plan, Phase II***

***Progress Report: Draft Framework for Action (Draft (12/20/05))***

CCDoTT originated the concept of a freight dedicated maglev system in its 2003 cycle of projects. For the last two years, extensive research and development, including work with several national laboratories and the Department of Transportation Volpe Research Center, have defined a maglev, cargo conveyor systems. These studies have also produced categorized comparisons of maglev conveyors with existing and proposed technologies for removing containers from the port and into the Southern California goods movement arena.

As the acknowledged leader by maglev technology providers (Transrapid America Inc, and General Atomics) in maglev freight, conveyor concepts, we submit added resolution to Table VI-3: "System Technology Enhancements" for the draft "Goods Movement Action Plan"

Technology Enhancement Measures	Operations	Equipment	Infrastructure Implications	Improves Velocity	Throughput Enhancing	Reliability	Reduces Congestion	Reduces Environmental Impact	Commercially Available	Homeland Security Applications	System Compatibility	Costs	Responsibility	Term
							Terminal Regional							
<b>Near-Port Maglev Cargo Conveyor</b>	√	√	√	√(1)	√ (1)	√(2)	√	√ (3)	√(4)	√ (5)	√(6)	TBD	P, TO	IT
<b>Inland Port Maglev Cargo Conveyor</b>	√	√	√	√(1)	√ (1)	√(2)	√	√ (3)	√(4)	√ (5)	√(6)	TBD	P,O	LT

Notes—from recently delivered paper (attachment (1)) to the "Urban Freight Conference"

- (1) Maglev systems have demonstrated speeds up to 350 mph. CCDoTT funded studies with the world's first maglev manufacturer indicate that container consorts of 20 containers each will move non-stop at 90 mph. A single bidirectional, maglev container conveyor is capable of a throughput of 5 million+ TEU out of the port per year. Expansions to the system can accommodate projected container volumes for the next fifty years.
- (2) Maglev cargo containers have no moving parts and make no contact with the guideway. Maglev's reliability far exceeds "steel wheel systems" since the weight of the cargo is distributed over several square meters rather than a few square centimeters. Also, the first embodiment of maglev technology has been in passenger travel. Over 20 million people have used the first commercial maglev in Shanghai without a single incident. Thus, maglev cargo conveyors will have a reliability exceeding any existing or proposed freight system.
- (3) Simply put, maglev is the most environmentally acceptable (pollution, noise, vibration, footprint) of any cargo transport known.
- (4) Maglev systems are commercially available from CCDoTT's two, aforementioned technology providers
- (5) Since maglev cargo conveyors are totally automated and run on an elevated guideway at significant speed, they are inherently secure. The conveyor nature of the system allows for organized passage through several, parallel x-ray portals, and automated selection and transport for quarantine measures. Additionally, the Maglev system, using empty containers, could be utilized as a rapid evacuation system from the port if a mass evacuation of the port became necessary and normal transportation means were overloaded or blocked.
- (6) Maglev cargo containers are not only compatible with rail and highway at the port and in goods movement processes, but also complement these existing infrastructures by easing congestion and serving as feeder systems to Inter-modal Container Transfer Facilities (ICTF) and railheads.